THE ECONOMICS OF MODIFIED MANURE HANDLING SYSTEMS FOR GREENHOUSE GAS REDUCTIONS

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Livestock farming is a major source of ammonia emissions. Net benefits of manure to an individual farmer are generally negative implying it is a waste product to be disposed of at minimum cost. Thus, reducing environmental damages from manure will require policy makers to encourage the adoption of practices to reduce nutrient levels. Options to reduce these emissions include; a) altering the nutrient content of the manure through ration changes or multiple stage feeding; b) adaptions to the stabling and storage of manure; and c) low ammonia applications such as incorporation of manure. Measures to reduce N content in the diet offer the lowest costs per unit emission reduction while the most costly are the measure to reduce ammonia volatilization from the barn and storage. These costs vary significantly between farm types and region, implying targeted policies and permitting flexibility in control options will be more cost effective than uniform regulations. The design of effective policies requires more information on costs and environmental impacts of alternative measures.

1. INTRODUCTION

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There are a number of environmentally significant gases which are associated with livestock barns, manure storage and the field application of manure. Gases released to the atmosphere from barns, manure management systems and land spreading of manure as fertilizer may have local impacts, contributing to air, land and water pollution. Some of these gases are also of concern from a global perspective since they contribute to global warming (the "greenhouse effect") and to the destruction of stratospheric ozone (Edwards and Wagner-Riddle, 1996). Management choices related to the creation, storage and application of manure can influence the level of these gases. However, the practices selected by the farmer, and thus manure pollution levels, depend largely on relative on-farm profitability rather than off-farm environmental concerns.

The purpose of this paper is to assess the current literature dealing with economic analysis of differing manure management systems. From this review we intend to reach some conclusions and suggest areas for further research regarding the costs of different manure handling practices on the level of greenhouse gas reduction. The next section of the paper reviews studies which have examined the optimal manure handling system for an individual producer. The objective in these studies is generally to find the system that minimizes the costs for the producer. The third section summarizes studies that have determined the costs of the alternative manure management systems in relation to their ability to reduce nutrient emissions. These studies tend to be from the Netherlands where concerns over ammonia levels are much greater than in Canada and policies have been subsequently implemented to reduce emissions from livestock operations. The fourth section will describe knowledge gaps in the literature and suggest areas for further research.

2. COST EFFECTIVENESS OF MANURE HANDLING SYSTEMS

The optimal manure-handling technology for an individual producer involves a systematic sequence of operations which must be selected from a large number and variety of

available structures and equipment systems. Narayanan and Stonehouse (1981) determine the manure-handling and utilization system that minimizes cost for a representative Ontario beef feedlot operator. Costs are minimized subject to meeting the requirements of nutrients for crops, timeliness in manure application, stipulated product supply requirement and land acreage availability. The optimal manure-handling system was found to be a liquid system with slatted floor, mechanical collection, solid separation, above ground storage, and tanker injection. Reducing the time available in the spring, prompts a switch in application method from tanker injection to irrigation which increases environmental damages and annual costs but decreases compaction. Increasing energy prices changes the optimal method to gravity collection of liquid manure and under-the-slat storage. Given the capital intensive nature of manure handling systems, the decisions on whether to own or hire the spreading and application equipment will depend on its capital cost in relation to the size of the operation.

Kelland and Stonehouse (1984) extended the model of Narayanan and Stonehouse (1981) to handle four livestock types (dairy, beef, swine and poultry) and additional alternatives of manure digestion and its by-products, manure composting and off-farm sales. They found no convergence toward any specific manure-handling system on different specialized types of livestock farms based on a criterion of cost minimization. Landreville (1987) extended the model further to examine the modifications that could be made to existing manure handling systems to reduce the manure handling cost of a farrow-to-finish operation. The study recommended that the quantity of manure applied in the spring and summer be increased so as to minimize damages from fall and winter applications and that the manure applied be incorporated within 48 hours to minimize plant nutrient losses. In addition, the field spreading should be done by a custom operator to avoid fixed ownership costs.

The costs of spreading liquid manure were estimated for three systems (tanker-broadcast, tanker-injection, and "hard-hose traveller" irrigation) by Fleming and Stoner (1982) based on a survey of 20 swine farms in Huron and Perth counties of Ontario. Costs

were calculated based on three sizes of operation. It was determined that travel time and application rate influence the spreading rate which consequently has a large influence on the cost to spread a given volume of manure. Therefore, this study attempted to put the three systems on an equal footing by assuming constants for these variable factors. Fleming and Stoner (1982) concluded that spreading 500 000 gallons of manure per year, a tanker-broadcast system will cost about $7.70 per 1 000 gallons spread. A tanker-injection system will cost about $11.30 per 1000 gallons for the same annual spreading volume. Based on 1 000 000 gallons of manure spread per year, a hard hose traveller irrigation system will cost about $13.70 per 1 000 gallons. This system had a high initial cost and therefore was not recommended for the smaller-sized farmer.

In a similar study, Lazenby (1995) evaluated alternative liquid manure handling systems based on 12 freestall dairy operations in Ontario. Four components (collection, transfer, storage and field application) were considered within each system rather than just application as in the Fleming and Stoner (1982) study. Costs included the ownership and operating costs of all the equipment, buildings and structures, and benefits consisted of the opportunity value of the manure nutrients to replace commercial fertilizer. The preferred system was an alley flush collection method with storage in a series of three earthen lagoons and application using a hose reel irrigation system. The alley flush system cost $130 per cow per year with the 250-cow herd, and $224 for the 100-cow herd. The earthen lagoon can cost as little as $2 per cow per year with the concrete storage being approximately 10 times more expensive. Consistent with the above studies, reel irrigation is the most economical method for farms pumping large volumes because of its cost structure (high fixed costs spread out over many years and low variable costs).

Roka and Hoag (1996) examined the effect of manure value on livestock production decisions for a representative North Carolina swine finishing operation. Both manure production (herd size and market weight) and manure disposal (treatment and cropping) decisions were simultaneously considered. Under all scenarios considered, manure value was

negative as the cost of disposal outweighed the value of contributed nutrients. Even though manure value was negative, it was small compared to the value of the primary pork product and consequently manure value had no impact on live weight decisions of market hogs. However, a negative net benefit for manure implies that it is a waste product so producers will tend to apply excessive amounts on lands closest to storage facilities (Roka and Hoag 1996).

Fleming et al. (1998) also examined whether manure is a valuable resource that can reduce fertilizer costs (positive net benefits) or if it is a waste by-product to be disposed of at minimum cost. The former implies policy makers should encourage nutrient recycling by integrating livestock and crop production while the latter implies encouraging the adoption of practices to reduce nutrient levels and thus environmental damage. The article measures the net benefit of swine manure to Iowa production conditions for two storage technologies (anaerobic lagoon and slurry basin), for two levels of field incorporation after application (immediate and none), and for two different target nutrients (nitrogen and phosphate). Net benefit is determined by the distance the manure has to be hauled and its nutrient content. Manure nutrient returns are maximized where high-nutrient-using crops are grown close to a medium sized swine finishing facility that stores manure using nutrient conserving methods. The value of manure is reduced if it is stored in an anaerobic lagoon and/or if it is surface applied (not incorporated) because nitrogen is lost to the atmosphere. On the other hand, it costs less to surface apply manure because less equipment is involved and the producer has greater flexibility with respect to timing of applications and suitable acreage. Fleming et al. (1998) also found that basing manure applications on phosphate levels rather than nitrogen, increases the value of manure nutrients because applied nutrients better match crop requirements. This also increases the cost of delivering manure because application rates on corn are reduced, hence more acres must be used for application. However, the profit-maximizing number of hogs and the profit levels under a phosphate standard are both greater than under a nitrogen standard. Fleming et al. (1998) also note that even for the situations where net benefits of manure are positive, it is the market value of hogs which will drive

swine production decisions given the relative value of manure nutrients compared to the value of the primary product of pork. Therefore the swine producer will minimize the cost of manure storage and delivery and simply accept what value there is in the manure nutrients generated.

3. COSTS OF EMISSION REDUCTIONS FROM MANURE HANDLING SYSTEMS

Several studies examine the costs of reducing ammonia emission on pig farms in the Netherlands. Three categories of measures to reduce ammonia emissions are generally considered; (1) ration adjustment; (2) changes in the barn and storage facility (covering or filtering); and (3) manure application method. Findings in each of these categories will be looked at in this order.

Measures to reduce dietary nitrogen appear to be cost effective in reducing nutrient excess. For example, using more phases in feeding regimes enables the protein needs of the animals to be met more efficiently. Giessen et al (1993) found feeding in more phases decreases N volatilization and N leaching by 16-19 percent and decreases costs on pig fattening farms while increasing costs on breeding pig farms. The cost per unit of N reduction is around -10 (Dfl/kg) for finishing farms and approximately 2 (Dfl/kg) for breeding farms. Baltussen and Hoste (1993) also found that changing the feeding system can reduce ammonia emissions by up to 18 percent at an extra cost of 3-4 guilders per fattening animal per year, with the costs varying according to the need for extra investment in blend feeding. Giessen et al (1993) estimate adding synthetic essential amino acids to the diet can reduce N emissions by a further 25 percent, with a reduction to 33 percent if feeds with low protein content are used. However, no costs are provided for these measures. Bloemhof-Ruwaard et al. (1995) claim the use of phytase in the diet can decrease the amount of phosphorus in the manure by 17 percent without a significant cost increase.

Adjustment measures for manure storage systems involve high investment costs and subsequently high costs per unit of emission reduction. Ammonia emission in barns can be

reduced by at least 50 percent by adopting an alley scraper system or a flush system but will increase N leaching by approximately 7 percent due to the higher N content in the manure. Hoste and Baltussen (1993) and Baltussen et al. (1990) estimated annual costs of 17 Dfl/animal for stench-traps, and 111 Dfl/animal for manure channel system adaptations with the associated percentage reduction in ammonia emissions being 9 percent and 30 percent, respectively. These authors also found that the only means to significantly reduce evaporation was large barn adaptions such as manure slides which cost approximately 111 Dfl/breeding pig or approximately 75 Dfl/kg of N reduced. Air cleaning systems that remove part of the ammonia can reduce N volatilization significantly, but the cost per unit of N reduced is high at 16-35 Dfl/kg (Giessen et al 1993). Manure storage covers reduce N volatilization from the storage by up to 90 percent but increase leaching due to the higher N content in the manure. Covers cost around 2-6 Dfl/m^3 (Baltussen et al. 1990) with the cost per unit of N reduced being approximately 20 Dfl/kg (Giessen et al. 1993).

The final area of manure handling in which emissions can be reduced is the method and season of manure application. Injecting the manure directly into the soil or cultivation of the land immediately after application can reduce N-volatilization by approximately 90 percent as compared to normal surface spreading (Baltussen et al. 1990). At the farm level, N-volatilization is reduced an average of 40 percent for pig operations but N leaching increases by 25 percent depending upon weather conditions (Giessen et al. 1993). The costs of incorporating manure into the field, which includes modifications to storage facilities less the reduction in inorganic fertilizer, is approximately 4 Dfl/m^3 or between 20-25 Dfl per kg of N reduced. Two final alternatives noted by Bloemhof-Ruwaard et al. (1995) as last resorts in the control of ammonia emissions on farms were mandatory central processing of manure and livestock reduction. Central processing as an alternative turns out to be very difficult due to choosing a location of a plant and the high production costs of processing compared to the cost of inorganic fertilizer. Mandatory livestock reduction was considered even more of a final resort due to the large economic consequences of unemployment and GNP reductions involved.

Klaassen (1994) estimates the costs of controlling ammonia emissions from livestock farms for 33 regions in Europe. As in the above studies, the abatement options include changes to the N content of the manure, adaptions in the stabling and storage of manure, and low ammonia applications of manure. Cost estimates for the different abatement options were based on country- and technology-specific data. The considerable variation among countries in terms of the structure of livestock population, the contribution of mineral fertilizer to total ammonia emissions, and expected growth, resulted in considerable variation in the average costs between countries for applying similar reducing techniques. For example, Klaassen (1994) estimated a 30 percent reduction of 1980 ammonia emissions for Austria (down to 60 kton NH3) would be relatively cheap (around DM 100 million annually) and marginal costs would be low (DM 7,000 per ton NH3). The relatively low costs are due to a forecasted stable emission level in the future and being able to reduce a large part of the emissions by applying low N manure at low costs. In contrast, a 30 percent reduction for the UK would be 17 times more costly and the volume of emissions controlled only 6 times greater. The higher costs in the UK are due to an expected increase in emission levels (so more have to be removed to obtain the 30% reduction) and more costly measures are necessary. Due to differences in average costs and agricultural structure, a regulatory approach prescribing the same techniques in every country, will be more expensive than setting country-specific emission ceilings.

4. KNOWLEDGE GAPS AND WORK FOR THE FUTURE

Based on the review of previous studies on the economics of manure handling systems, several conclusions emerge. One is that while manure can be a net benefit in some cases, its value will be small compared to the livestock that is produced. Thus, individual farmers will tend to dispose of the manure at minimum cost. Efforts to reduce emissions should thus focus on abatement activities as opposed to encouraging nutrient recycling through integration of livestock and crop activities. Secondly, abatement options associated

with changing the composition of the manure are more cost effective in reducing greenhouse gas emissions than adjustments to stabling and storage. Third, the costs of each abatement activity vary significantly depending upon farm conditions. Fourth, little is known about the effect of a combination of abatement measures. Finally, there is a great deal of uncertainty in the level of emissions reduced by a given practice, the cost of that practice, and consequently the cost per unit of emission reduced.

Economists cannot effectively analyze the overall economic impacts jointly to farmers and the public (the so-called net social welfare impact) of manure management without the help of technical scientists. To date, economists have worked with very poor estimates of both off-farm benefits and off-farm costs; that is, they do not have legitimate, concrete figures relating the downstream/off-farm benefits and costs of manure to soil enhancement and downstream watercourse pollution rates respectively (Goss et al., 1993). More research is needed related to NH4 and N loss/retention rates associated with manure handled in different forms and in various ways. Particularly, more research should be encouraged into loss/retention rates associated with different livestock housing systems, and with different handling methods at each stage of the manure-handling process from collection through storage, field distribution and soil incorporation. Related research work could usefully investigate remedial measures for reducing N losses, from the points of view of technical feasibility and of economic viability. As mentioned by Leger et al. (1991), economic survival in an intensely competitive agricultural production sector increasingly is demanding good financial management skills and the ability to function on an efficient and productive basis. For manure-handling operations, this means striving for minimum cost alternatives, while incorporating environmental considerations.

Information focusing on manure-handling system alternatives and inherent costs should prove extremely helpful to farmers attempting to make decisions about manure system selections with economics, energy efficiency, and environmental care in mind. Research into alternative manure systems could establish more accurate figures on nutrient and organic

matter retention rates, surface and ground water leaching rates, and the off-farm as well as the on-farm economics picture. This information must then be incorporated into a model (or system of models) that links the abatement measures to emission levels. Such information is necessary to evaluate the effectiveness of alternative management practices and the design of policies to encourage the adoption of these practices.

An example of the type of work required is the development of decision support systems that will help fill some of these information gaps and ultimately help farmers make more "informed" and rational decisions about manure system choices. The University of Guelph formed a team in 1995 to develop such a computer-based decision support system which deals with manure management from the feed input, manure release and handling in the barn, storage, field application and transformation in the soil, to incorporation of nutrients in crops (Goss et al., 1998). The computer program, called MCLONE, will soon be available to assist in the choice of manure management alternatives from defecation through to long-term storage and application. This knowledge-based program connects the user's preferences with stored knowledge on cost, labour use, odours, nutrient losses and potential environmental impact. The program runs on a personal computer and provides estimates of the ranking of the chosen system on a scale of 1 to 10. The user is able to change the weighting of the determining factors and obtain a new ranking based on these changes.

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